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Utilization of Cheese Whey for Wine Production

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16. ABSTRACT

Wine was successfully produced in the laboratory from cheese whey. The method used involves the deproteinization of either sweet (cheddar cheese) whey or acid (cottage cheese) whey by heat or ultrafiltration, the addition of sulfur dioxide to stabilize the whey by Kruyveromyces fragilis. Since the lactose will yield only 2% or 3% alcohol, it is necessary to add dextrose and to ferment it with Saccharomyces cerevisiae to increase the alcohol content of whey wine. Yeast nutrients such as nitrogen and addition of B-vitamins were found to be unnecessary for whey wine fermentation, as the whey itself contains sufficient nutrients for yeast growth.

At least two rackings are necessary before the wine is fined with bentonite. Whey wine is filtered before bottling, and pasteurization is required for a sweetened whey wine, unless an aseptic method is used.

Results are quite encouraging. The whey wine was acceptable to a great majority of tasters, who preferred it slightly sweet. Blends of whey wine with fruit and berry wines were also liked. Whey wine with favoring materials such as citrus and cola also showed promising results.

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UTILIZATION OF CHEESE WHEY FOR WINE PRODUCTION

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory -- Cincinnati (IERL--Ci) assists in developing and demonstrating new and improved methodologies tha will meet these needs both efficiently and economically.

This report is a product of the above efforts. It describes research efforts to convert cheese whey into a useful by-product--wine. The results were quite encouraging, and it is recommended that the efforts be continued on a larger scale so as to conduct marketing feasibility studies.

For further information regarding this report contact the Food and Wood Products Branch, Industrial Pollution Control Division, Industrial Environmental Research Laboratory--Ci, Cincinnati, Ohio 45268.

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ABSTRACT

The objective of fermenting whey into wine is to provide another outlet for the utilization of the vast quantities of whey that are a by-product of cheesemaking.

Utilization of whey for wine production requires few if any energy resources. The entire whey is utilized; no removal of water is necessary. Furthermore, whey can be fermented by small cheese plants for wine production, since no elaborate or expensive equipment is required.

The method used involves the deproteinization of either sweet (cheddar cheese) whey or acid (cottage cheese) whey by heat or ultrafiltration, the addition of sulfur dioxide to stabilize the whey before fermentation starts, and the fermentation of lactose normally present in whey by Kruyveromyces fragilis. Since the lactose will yield only 2% or 3% alcohol, it is necessary to add dextrose and to ferment it with Saccharomyces cerevisiae to increase the alcohol content of whey wine. Yeast nutrients such as nitrogen and addition of B-vitamins were found to be unnecessary for whey wine fermentation, as the whey itself contains sufficient nutrients for yeast growth.

At least two rackings are necessary before the wine is fined with bentonite. Whey wine is filtered before bottling, and pasteurization is required for a sweetened whey wine, unless an aseptic method is used.

Results are quite encouraging. The whey wine was acceptable to a great majority of tasters, who preferred it slightly sweet. Blends of whey wine with fruit and berry wines were also liked. Whey wine with flavoring materials such as citrus and cola also showed promising results.

This report was submitted in fulfillment of the requirements of Project No. R01101 awarded by the Environmental Protection Agency to the Oregon State University.

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The cooperation of the following cheese plants in providing cheese whey for this project is very much appreciated: Fairmont Cheese Company, Olympia, Washington; Mayflower Farms, Coos Bay, Oregon; Coquille Valley Dairy Cooperative, Bandon, Oregon; Tillamook County Creamery Association, Tillamook, Oregon; and Sunnybrook Dairy, Corvallis, Oregon.

SECTION I

INTRODUCTION

Effective and economical methods of utilising whey are essential if cheese plants are to remain competitive with other segments of the food processing industry. The drying of cheese whey is limited by some adverse economic considerations. An efficient whey drying operation requires more whey than most cheese plants produce. Also, large volumes of water would have to be removed, thus requiring considerable consumption of our diminishing energy resources (2).

Utilisation of whey for wine production requires few if any energy resources. The entire whey is utilised; no removal of water is necessary. Furthermore, whey can be utilised by small cheese plants for wine production, since no elaborate or expensive equipment is required.

Acceptable wine also has a higher monetary value than other products. From 100 pound (220 kg.) of milk, 10 pounds (22 kg.) of cheese is produced; the remaining 90 pounds (193 kg.) is whey. Ten pounds of cheese can be retailed for approximately $15; 90 pounds of whey can be made into 10 gallons (37.85 liters) of whey wine and be retailed for about $50, assuming $1 per fifth. The economic advantage of utilising whey for wine production is obvious.

The use of whey as a fermentation substrate has appealed to microbiologists, food scientists, cheese processors, and others who have been faced with the problem of upgrading this raw material into useful products which can be produced and marketed on a profitable basis. Whey has been used or suggested as a substrate for the manufacture of yeast, alcohols, lactic acid, vitamins, vinegar, and alcoholic beverages. The production of wine or other popular alcoholic beverages. The production of wine or other popular alcoholic beverages from whey has remained a laboratory curiosity for many years(5).

As early as 1868, a U.S. patent was granted Baldwin(1) for the production of a cordial from whey. In 1945 and 1952, Engel(3,4) was issued several patents for the production of an alcoholic beverage, in which sucrose and whey were fermented with baker's yeast. A variety of beer-like products have also been produced from whey in Germany(6).

The U.S. cheese industry is in most urgent need of a development of whey by-product that would not encompass relatively expensive processes for water removal. The fermentation of sugar-fortified whey by selected wine yeast and the production of an acceptable whey wine may represent a 'near ideal' solution for the whey disposal and utilisation dilemma of the U.S. cheese industry. The production of an acceptable wine by whey fermentation may be the means of transposing a 'cost of doing business' into a 'profit opportunity.'

SECTION II

CONCLUSIONS

The production of wine from whey is a good way to utilize some of the whey that is polluting the environment. Straight whey wine, flavored whey wine, and whey wine blended with fruit or berry wines show promise for commercial development.

Both sweet and acid wheys showed equal results. A great majority of tasters prefer the whey wine slightly sweet. Blends of whey wine with fruit and berry wines were also liked with the red raspberry-whey wine blend on top of the preference list.

Costs for wine making should be much lower than other methods of whey utilization since few if any energy resources are required. Furthermore, capital outlay is low because no elaborate or expensive equipment is required.

The remaining solids should not be difficult to dispose. The milk protein can be used as food ingredient for human consumption, and the yeast protein should be suitable for animal feeds.

SECTION III

RECOMMENDATIONS

Pilot plant development and marketing feasibility studies should be made for whey wine. Such studies are currently underway at the Foremost Foods Company Research and development Center in Dublin, California, under EPA grant No. 803063 entitled 'A Demonstration Project on the Utilization of Cheese Whey for Wine Production.'

Future projects should include the testing of flavoring materials to make flavored whey wine. The production of whey brandy is also a possibility.

Industrial alcohol production by whey fermentation is technically possible. The economic factor against other methods of alcohol production should be considered, however.

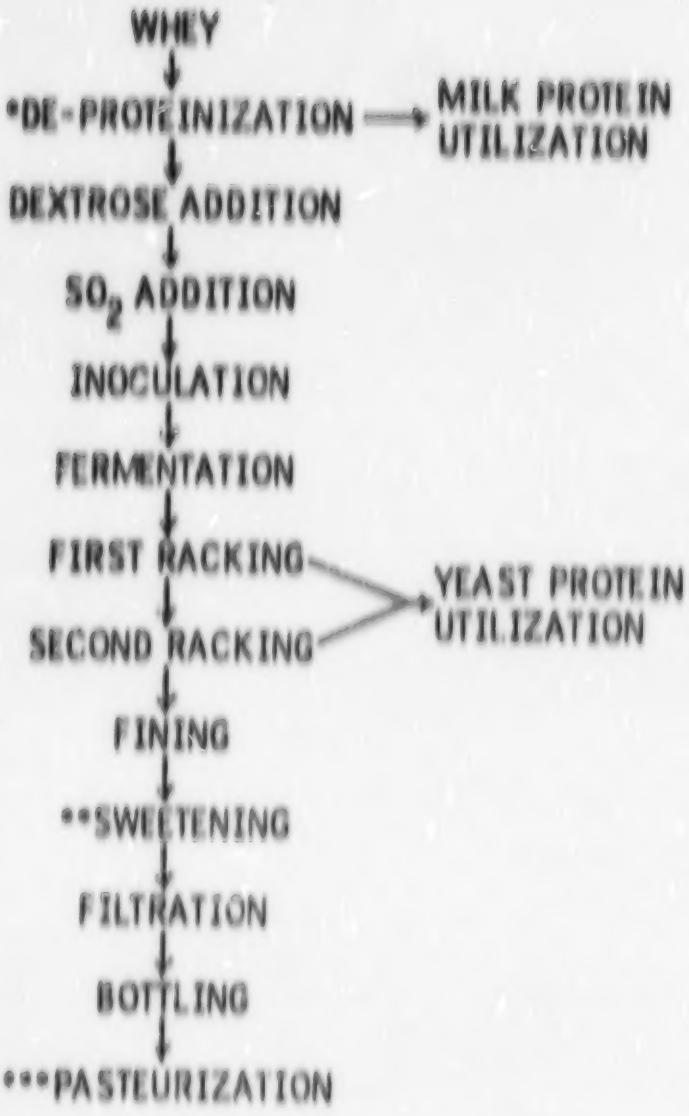
SECTION IV

METHODS

Whey for this project was obtained from cheese plants located in Oregon and Washington. Both sweet (cheddar cheese) whey and acid (cottage cheese) whey have been used for the experiments.

The general scheme of wine production from whey is shown in Figure 1. For making clear whey wine, it is necessary to deproteinize the whey by heating it to 180°F in steam-jacketed kettle for 5 minutes. The protein thus precipitated is removed and could be utilized as a food ingredient. About 22% dextrose is added to the clear whey, depending on the concentration of alcohol desired in the wine. After cooling, 100 ppm of sulfur dioxide is added for stability. The whey is then inoculated with yeast and the fermentation carried out in glass carboys. Fermentation commences shortly thereafter. When fermentation is completed and yeast cells are settled, the wine is racked by decantation. This procedure is repeated once or twice. The lees are separated by filtration. They are a good source of protein and could be used in foods or animal feeds. The quantity of the lees is about 2% of the wine by volume. The wine is then aged and clarified by a fining agent (mixing with 0.2% bentonite) and sweetened if desired. To insure clarity, the wine is filtered through an Ertel pad filter before bottling. Sweet wine should be pasteurized or handled aseptically to prevent secondary fermentation.

Pasteurization requires the elevation of temperature from ambient to 185°F (88°C). Energy requirement is 185-72 or 113 B.t.u. per pound, approximately 950 B.t.u. per gallon (3.785 liters).



*Omitted if a cloudy wine is produced
**Omitted when a dry wine is produced
***Omitted if an aseptic method is used

Figure 1. Production of sweetened clear whey wine.

SECTION V

RESULTS AND DISCUSSION

Yeast

Table 1 shows the effect of different wine yeast strains on the fermentation rate of whey wine. Of the five yeasts tested, Montrachet fermented the fastest, taking an average of 7 days to ferment whey to wine at room temperature. Champagne and sherry were only slightly slower, taking 8 days. Port took 12 days, and burgundy 14 days. All yeasts produced the same alcohol content at the end of the fermentation, above 10% by volume. Sensory evaluations conducted thus far reveal no conclusive differences in flavor between wines fermented by different yeast strains. It appears that Montrachet is the preferred yeast for whey wine fermentation because of the more rapid rate of fermentation.

Table 1. Effect of Yeast Strains on Fermentation Rate

Yeast Strain	Time for Completion of Fermentation (days)	Fermentation Rate ($days^{-1}$)	Alcohol Production (%)
Montrachet	7	0.14	10.35
Champagne	8	0.13	10.25
Sherry	8	0.13	10.00
Port	12	0.08	10.20
Burgundy	14	0.07	10.10

Temperature

Three fermentation temperatures were tested for their effect on the rate of fermentation and flavor of wine. Results are shown in Table 2. At the incubator temperature of 90°F, it took an average of only 4 days for Montrachet yeast to ferment whey to wine; at room temperature, it took 7 days. In a refrigerated room at 55°F, fermentation was the slowest; 17 days were required for completion. The slightly lower alcohol content of the wine fermented at 90°F could be due to the volatile nature of alcohol at higher temperatures.

Table 2. Effect of Temperature on Fermentation Rate

Temperature (°F)	Time for Completion of Fermentation (days)	Fermentation Rate ($days^{-1}$)	Alcohol Production (%)
55	17	0.06	10.65
72	7	0.14	10.51
90	4	0.25	10.20

Sensory evaluation revealed no significant difference between the wine fermented at 55° and that at 72°F. The wine fermented at 90°F, however, was definitely disliked by the panelists. This could be due to the rapid deterioration of the whey at that temperature. In the interest of energy conservation, fermenting whey wine at room temperature appears to be the most desirable.

Nutrients

Nitrogen as a yeast nutrient was supplied by a mixture of 50% ammonium phosphate and 50% ammonium chloride. This mixture was tested at concentrations of 500 and 1000 ppm. Vitamins B_1 (thiamin) and B_2 (riboflavin), known also to increase the efficiency of yeast fermentation, were tested at 5 ppm respectively. The results in Table 3 show that the addition of yeast nutrients was not found to be necessary for fermentation of whey wine. Neither the fermentation rate, nor the percentage of alcohol produced was increased significantly. It appears that the whey itself contains sufficient nutrients for yeast growth, and additional nutrients are of no value.

Table 3. Effect of Nutrients on Fermentation Rate

Nutrient	Time for Completion of Fermentation (days)	Fermentation Rate ($days^{-1}$)	Alcohol Production (%)
Control	7	0.14	10.1
250 ppm $(NH_4)_2HPO_4$ + 250ppm NH_4Cl	8	0.13	10.2
500 ppm $(NH_4)_2HPO_4$ + 500 ppm NH_4Cl	7	0.14	10.1
5 ppm Vitamin B_1	8	0.13	10.1
5 ppm Vitamin B_2	8	0.13	10.3

Preservatives

Sulfur dioxide and sorbic acid were tested as preservatives for whey wine. The effectiveness of the preservatives was determined by plate counts of viable microorganisms at different time intervals. Results are shown in Table 4. After 9 weeks, some samples had counts of a few hundred microorganisms per ml. These are considered as low counts for wine. All the wine samples had a decrease in counts at subsequent intervals. At the end of 19 weeks, all samples are virtually sterile, including the control. Evidently, the combined preservation effect of alcohol and lactic acid present in the wine offers sufficient protection for dry whey wine, and no chemical preservatives are needed. Wine treated with 100 ppm SO_2, however, seems to have a cleaner taste and perhaps would be a desirable practice. The sorbic acid treated wines exerted some effect on the flavor of the wine. The degree of off-flavor was in proportion to the preservative concentration.

Table 4. Effect of Preservatives on Viable Microorganisms in Whey Wine

Preservative (ppm)	Plate Counts (colonies/ml) after 9 weeks	12 weeks	15 weeks	19 weeks
Control	800	110	4	0
SO_2:				
50	1300	58	9	3
100	8	1	1	0
200	0	0	0	0
300	0	1	0	0
Sorbic Acid:				
100	400	135	1	1
200	18	0	1	0
300	30	167	0	0
400	0	0	0	0

Clarifying Agents

To make clear whey wine, bentonite has shown promise as a clarifying agent as shown in Table 5. This clarifying agent, when used in a concentration of 0.5%, showed excellent results for clarifying cloudy

whey wine. It was observed that deproteinised whey produced cloudy whey wine, due to the activity of the yeast.

Sparkolloid (a trade name for a polysaccharide product) and casein were found to be poor clarifying agents for whey wine. Adjusting the pH of the wine with potassium carbonate to the iso-electric point of whey protein (pH 5.1-5.3) facilitated protein precipitation. The problem here, however, is that at the iso-electric point, the wine is low in acidity, and tastes flat.

Tannin appears to be a good clarifying agent, except that it may impart an off-flavor to the wine.

Table 5. Effectiveness of Clarifying Agents for Whey Wine

Clarifying Agent %	Clarifying Action			
	Poor	Fair	Good	Excellent
Bentonite:				
0.20	x			
0.25		x		
0.30			x	
0.50				x
Sparkolloid, Cold:				
0.01-0.20	x			
Casein:				
0.01-0.20	x			
Tannin:				
0.010	x			
0.015		x		
0.020			x	
K_2CO_3:				
0.44			x	
0.48				x
0.52			x	

Cloudy and clear whey wines were compared by gas-liquid chromatography. The instrument used was a Varian Aerograph 1200 with a hydrogen flame ionization detector. Samples of whey wines were injected directly.

The column used was 12 foot x 1/8 inch stainless steel packed with 5% BDS (butanediol succinate) and 0.05% isopal on Chromosorb Q. The column was conditioned at 170°C and maintained at 135°C. The range was set on 1 and the attenuation was 128. The nitrogen flow was 30 ml/minute, the sample size was 10 ul, and the chart speed 30 inches/hour.

Typical gas chromatographs are reproduced in Figure 2. It is seen that both the cloudy and the clear whey wines produced identical chromatogra-- indicating that the volatile components present in whey wine were retained after clarification. Peak 2 of the clear wine, however, is lower than that of the cloudy wine, indicating that perhaps some loss of this component may have occurred during fining and filtering.

Fruit-Whey Wines

The possibility of blending fruit and berry wines with whey wine was investigated. Raspberry, strawberry, blackberry apple, and pear wines were prepared according to methods prevailing in the Pacific Northwest(7). Each fruit or berry wine was blended with whey wine on a 50-50 basis. All the berry blends of whey wine were considered acceptable in the flavor preference tests that were conducted (Table 6). The apple and pear blends were not considered acceptable. This is probably because these two fruits are generally weaker in flavor, as compared to the berries.

Flavored Whey Wines

The possibility of flavoring whey wine with synthetic flavors was investigated. Citrus, cola, and raspberry flavors were evaluated. The cola-flavored wine left a medicinal after-taste, and was not acceptable. A 50-50 blend of whey wine and Coca-Cola, however, was a more acceptable product. The raspberry-flavored whey wine was not comparable to the natural raspberry-whey wine blend previously tested. The flavored raspberry wine tasted synthetic, without the aroma of true raspberry. The citrus-flavored whey wine was considered the best product of the three flavored wines tested. The product has a pleasing taste which resembles some citrus-flavored pop wines currently selling on the market.

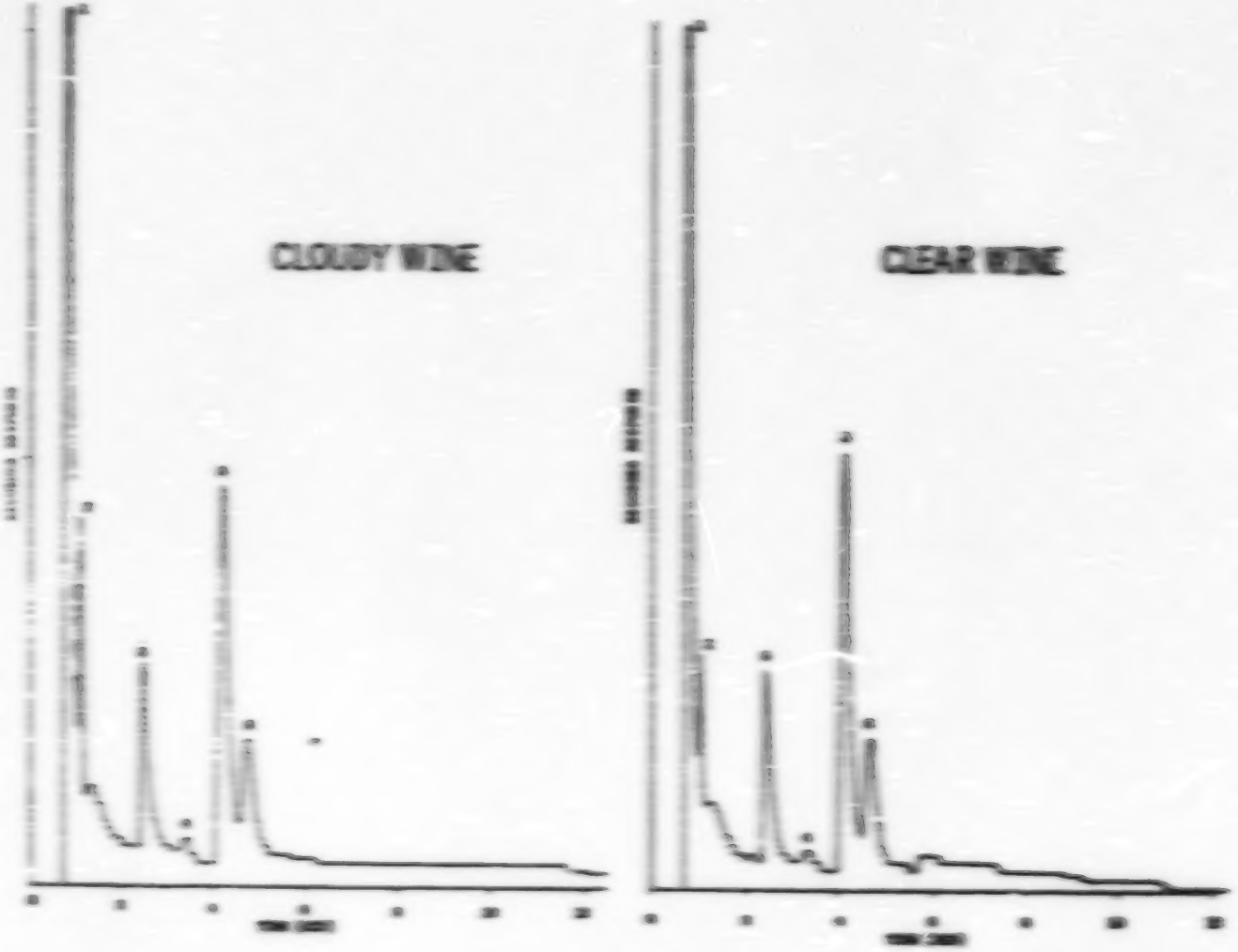


Figure 2. Gas chromatogram of clear wine.

Carbonation

Carbonation was attempted on the flavored whey wines. When a wine was carbonated to a pressure of 2.1 volumes of CO_2, it had a nice head when poured, with bubbles in the glass. Testing of a commercial beer and Coke for pressure gave 2.1 volumes of CO_2 for beer and 3.1 for Coke.

Acceptance

Whey wine, fruit and berry blends, and citrus-flavored wine were submitted for sensory evaluation by University personnel, the dairy industry, and other groups. A hedonic scale of 1-9 was used for scoring. A score of 5 implies the sample is neither desirable nor undesirable. A mean score above 5 generally indicates the sample is desirable. The higher the score, the higher the desirability. Any score below 5 is rated undesirable.

Table 6 shows the results of the sensory evaluation tests conducted. It is seen that, with the exception of the clear dry whey wine and the apple and pear blends, all wines were rated with a relatively high degree of preference by the panelists. The raspberry-whey blend received the highest rating of 6.9. Clear dry whey wine was rated the lowest, 1.6, with apple and pear blends rated just below the neutral point of 5.

Table 6. Results of Sensory Evaluation Tests for Various Whey Wines

Wine Type	Number of Panelists	Mean Score
Whey, Cloudy, Sweetened	109	5.2
Whey, Clear, Dry	36	1.6
Whey, Clear, Sweetened	145	6.1
Raspberry-Whey, Sweetened	126	6.9
Strawberry-Whey, Sweetened	25	6.4
Blackberry-Whey, Sweetened	25	6.4
Apple-Whey, Sweetened	25	4.6
Pear-Whey, Sweetened	25	4.7
Whey, Citrus-Flavored, Sweetened	50	5.5

One special wine tasting was conducted with a large group during the 1975 Oregon Dairy Industries Conference. A sweetened clear whey wine and a sweetened raspberry-whey wine were submitted to the group of over 300 people for tasting. One hundred and seventy-seven persons completed ballots. The results are summarized in Table 7. It is noted that the majority of the participants liked the clear whey wine or the raspberry wine blend. Only 7 out of the 177, or approximately 4% of those tasting, disliked both samples.

It should be noted that the wine samples were evaluated by a different number and varied groups of people in some cases. While the results may serve as an indication of the relative degrees of preference for the products, large scale consumer acceptance tests of each product must be conducted.

Table 7. Flavor Preference Evaluation by Oregon Dairy Industry Group

Flavor Evaluation Statement	Ballot Count	% Preference
I Like the Raspberry-Whey Wine	123	69.5
I Like the Clear Whey Wine	47	26.6
I Like Neither	7	3.9

Whey Beer

Attempts were made to prepare a whey beer using whey, malt, dextrose, and hops. Fermentation was completed in 9 days. However, the whey beer so prepared lacks the characteristics of a barley beer. A new malt syrup with hop extract already added was tried with better results; but the whey beer was still not acceptable. In contrast, beer made in the regular manner (without whey) resulted in a very acceptable product, indicating the problem was with the whey. Combinations of this regular beer and whey beer were tried in the following ratios:

Whey Beer	Regular Beer
25%	75%
50%	50%
75%	25%

Only the first one, with 25% whey beer, was at all acceptable.

Charcoal helped to remove the objectionable whey flavor of the beer. However, when enough charcoal was used to remove all of the objectionable flavor, the characteristic beer flavor was also removed. It is concluded that it would be most difficult to produce a beer from whey that would taste exactly like the beer we are familiar with. Only a beer-like beverage is possible, which might be acceptable to some cheese-loving people.

Stability and Packaging

Whey wine packaged in clear bottles and exposed to strong light showed a definite decrease in stability. The light-exposed wine became hazy after 6 weeks, while the same wine stored in a dark place was still in excellent condition after 9 weeks.

Sweetened and unpasteurized whey wine has a stability of only 3 1/2 weeks disregarding varying conditions of storage and types of containers used. However, unsweetened and unpasteurized, or sweetened and pasteurized whey wines are still stable after 7 weeks. This indicates that stabilization of sweetened whey wine is necessary, either by pasteurization or aseptic handling.

Long-term stability studies showed that it is possible to store whey wine for as long as 8 months, depending on the condition of the storage. The stability results for all the wine types can be summarized as follows:

1. The wine should be handled aseptically or pasteurized if it is sweetened.
2. Storage in dark bottles is better than in clear bottles, especially from a flavor standpoint.
3. Storage in the dark is preferable to storage under lights.
4. Storage at 40°F is better than at 72° or 90°.
5. Storage of a pasteurized sample at 40°F results in the best long term preservation of quality.

Acid Whey

Wine made from acid (cottage cheese) whey has characteristics comparable to that of wine made from sweet (cheddar cheese) whey.

Taste testing conducted using panels of experienced tasters indicated that a difference is noticed between cottage cheese whey wine and cheddar cheese whey wine due to their difference in acidity. When the acidity was adjusted equal, no significant difference was noted by the tasters.

Lactose Utilization

In the interest of utilising the lactose present in whey, Kruyveromyces fragilis was used to ferment the lactose in deproteinised acidy whey. Results indicated that an incubation temperature of 30°C is necessary for a good K. fragilis fermentation. It was also found that at least 100 ppm of SO_2 is necessary to help preserve the whey before fermentation starts. K. fragilis fermentation can be completed in 5 to 7 days, with an alcohol yield of up to 1%. By utilising the lactose, only 16% of dextrose was needed for the subsequent Montrachet yeast fermentation. Compared to the 22% used previously, there is a saving of 6% dextrose, which is equivalent to a half pound of dextrose per gallon. Assuming the price of dextrose is 20 cents a pound, this amounts to a saving of 10 cents per gallon of wine. The time required to convert whey to wine, however, is about twice as long when lactose is utilised.

The saving of $100 per 1,000 gallons is reduced where a sweet wine is desired. The wine with lactose fermented out requires more sugar for sweetening. Approximately 2% more sugar is required to compensate for the sweetness lost due to lactose utilization.

Analysis of the K. fragilis-fermented wine showed only 0.02% lactose remaining, indicating that the lactose conversion was quite complete.

The laboratory personnel working with the whey wine project can distinguish between the wines fermented with and without lactose utilization, but a taste panel consisting of 25 people in the Department of Food Science and Technology judged no significant difference between the two samples. The samples were adjusted to equal sweetness and acidity before they were presented for tasting. Repeated taste testing showed the same results.

SECTION VI

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SECTION VII

PERTINENT PUBLICATIONS

1. Yang, H.Y. and Berggren, K.E., "A Two-Stage Fermentation System for Whey Wine Production," Proceedings of the Third National Conference on Water Reuse, Cincinnati, Ohio. 3:542-545. Sponsored by the American Institute of Chemical Engineers and U.S. Environmental Protection Agency Technology Transfer.

2. Yang, H.Y., Bodyfelt, F.W., Berggren, K.E., and Larson, P.E., "Utilization of Cheese Whey for Wine Production." Proceedings of the Sixth National Symposium on Food Processing Wastes, Madison, Wisconsin. Sponsored by the U.S. Environmental Protection Agency.

3. Larson, P.E. and Yang, H.Y., "Some Factors Involved in the Clarification of Whey Wine." Journal of Milk and Food Technology. In print.